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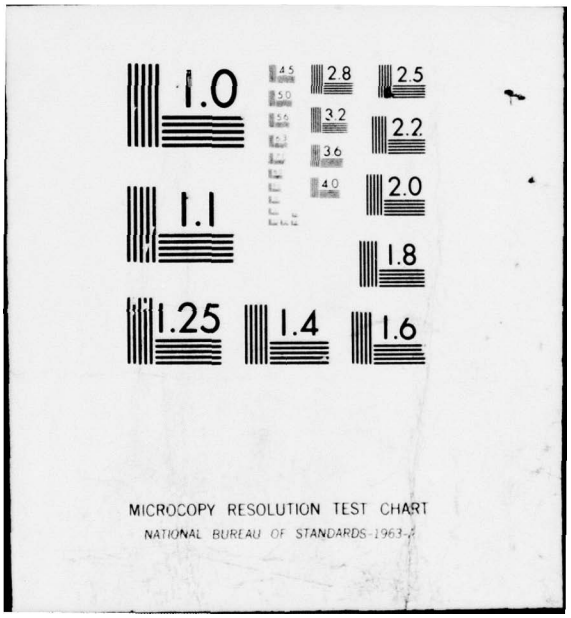
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VELA NETWORK EVALUATION AND AUTOMATIC PROCESSING RESEARCH

QUARTERLY REPORT NO. 1

1 OCTOBER 1976 TO 31 DECEMBER 1976

TEXAS INSTRUMENTS INCORPORATED
Equipment Group
Post Office Box 6015
Dallas, Texas 75222

Contract No. F08606-77-C-0004
Amount of Contract: $560,000
Beginning 1 October 1976
Ending 30 September 1977

Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER
Alexandria, Virginia 22314

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Monitoring Research Office
ARPA Program Code No. 7F10
ARPA Order No. 2551

6 January 1977

Acknowledgment: This research was supported by the Advanced Research Projects Agency, Nuclear Monitoring Research Office, under Project VELA-UNIFORM, and accomplished under the technical direction of the Air Force Technical Applications Center under Contract Number F08606-77-C-0004.

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Seismic Source Parameters
Seismic Path Corrections

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This first quarterly report summarizes progress under the VELA Network and Automatic Processing Research Program, Contract Number F08606-77-C-0004, during the period 1 October 1976 to 31 December 1976. Work in the following areas is summarized: - -

- Evaluation of ILPA and SRO data,
- Development of detection methods, → next page

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- Methods of extracting long-period event waveforms,
- Interactive seismic signal processing,
- Determining path corrections and extracting source parameters from long-period data.

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SECTION I
INTRODUCTION AND SUMMARY

This first quarterly report summarizes the progress made during the period between 1 October 1976 to 31 December 1976 in the VELA Network Evaluation and Automatic Processing Research program being carried out by Texas Instruments Incorporated at the Seismic Data Analysis Center (SDAC) in Alexandria, Virginia. The five program tasks are:

- Evaluate the performance of the Iranian Long-Period Array (ILPA) and the Seismic Research Observatories (SRO).
- Develop advanced methods for detecting seismic events and evaluate the event detection capability of postulated networks of seismic detectors.
- Extract seismic event waveforms given the location and origin time of an event.
- Develop and demonstrate function processes for interactive signal processing; standardize and automate the processing functions; also demonstrate their feasibility for the graphics processing of events.
- Compute instrument and path corrected spectra of a network of long-period seismic sensors and estimate seismic source parameters.

A Research Objective Plan was drawn up and approved for performing these tasks.

For both the ILPA and SRO data evaluations, work was concentrated in the following areas:

- Create a data base which is sufficient for evaluation of the stations and networks.
- Maintain data preparation software which is primarily the conversion of edit and beamform programs to the Terminal Support (TS) system.
- Prepare software to filter and plot data.
- Perform the routine signal processing and analysis needed to evaluate each station separately and to evaluate all stations as a network designed to locate and measure earthquakes and presumed explosions.

To develop advanced methods for detecting seismic events, five research tasks are being pursued. These are as follows:

- Determine the feasibility of using frequency dependent detection algorithms.
- Perfect and test methods for improving an automatic detector's capability to accurately time the arrival of seismic events.
- Determine the feasibility of using an adaptive beamformer to detect weak signals generated by seismic events.
- Develop an automatic method to associate the detections of an event received at a sub-set of seismic stations and to predict the arrival times of event phases at all stations of the network.
- Improve the accuracy of estimating a seismic network's capability to detect events of a given magnitude and location.

To develop event waveform extraction techniques, two tasks are being performed as follows:

- Extract long-period bodywaves from edited single sensor three component data and from array data.
- Cascade several methods of long-period event waveform estimations to optimize the extraction of weak signals.

To develop interactive graphics signal analysis capability the following three tasks are being performed:

- Standardize seismic processing functions for performing discrimination analysis.
- Extend the Interactive Seismic Processing System (ISPS) by developing a seismic programming language to generate displays, plots, and tables from data and information files stored on the disk; and which can perform simple analysis functions on this data.
- Develop software for transfering data to a mass store.

The final program task is to derive accurate transmission path corrections and source parameters from long-period data. This is broken down into three tasks as follows:

- Use newly developed and existing software for spectral analysis corrected for instrument response, path attenuation, and dispersion; also compare these to theoretical spectra and radiation patterns derived from the best fit source model as a means of estimating the source parameters associated with an event.

- Form a suitable data base with long-period waveforms measured at a large number of stations providing adequate azimuthal coverage of the event.

SECTION II
ILPA AND SRO EVALUATION

A. CURRENT STATUS

For both of the ILPA and SRO data evaluation tasks, work was concentrated on creating a suitable data base and on creating software needed to adequately estimate the capability of each station and of combined stations to detect and identify events from regions of surveillance interest. Events reported by the Norwegian Seismic Array (NORSAR) were regionalized using the system given by Flynn and Engdahl (1965). Events, from those regions in Eurasia with one hundred or more events reported between 22 December 1975 and 30 September 1976, were put into the data base. A plot program was completed to display filtered data with suitable vertical and horizontal scaling and annotation. Routine signal processing and analysis began this quarter. The routine processing consists of quality checking the data, of a visual detection decision, and of long-period data measurements of the surface wave magnitude of events detected at periods of twenty, thirty, and forty seconds. The magnitudes were measured automatically by a program just developed to replace more error prone mannual measurements of magnitude.

B. FUTURE PLANS

During the next quarter work will be concentrated on the following areas:

- Routine signal processing and analysis.
- Noise analysis.

The routine analysis will be performed on events previously processed with manual magnitude measurements, so that all of the magnitude data will be derived on the same basis of using the automatic method. In starting the analysis of short-period and long-period noise our goals are as follows:

- Re-check noise analysis programs used during the last contract period.
- Edit noise samples and beamform ILPA noise samples.
- Maintain and create any new programs necessary for the noise analysis.
- Begin to compile noise analysis results.

SECTION III
DETECTION METHODS

A. CURRENT STATUS

Software for performing frequency dependent detection and for generating detection statistics is now being tested. A program which generates time varying phase measurements was run on some long-period events to evaluate visual detectability and to come up with possible automatic detection algorithms. These are expected to provide more accurate timing of the onset of long-period surface waves. Last year, an attempt was made to apply an adaptive beamforming algorithm to the detection of weak short-period signals. The results indicated marginal gains of one to two dB for high signal-to-noise ratio (S/N) events and zero gain for weak signals. To possibly improve on these results, a new research version of the adaptive beamforming (ABF) program was written in FORTRAN for the TS system. By modifying this program and testing it on data, new ABF algorithms will be tested to determine their effectiveness in detecting weak signals. Also other applications may be considered such as first motion detection, coda suppression, later phase detection, and multiple event detection. Detection association processing and network capability analysis are in the planning stage.

B. FUTURE PLANS

The following developments are expected in the next quarter:

- Complete software development of the frequency dependent detector and begin testing with KSRS data by comparing its detection results to a broadband detector.

- Derive a phase detector algorithm for optimum timing of the onset of long-period surface waves and begin software development.
- Complete testing of the new ABF program and select suitable applications for testing.
- Maintain the detection association processor (DAP) software and test modifications with simulated network detection bulletins.
- Maintain the network capability and evaluation software and begin runs designed to remove bias in estimations of network capability.

SECTION IV
EXTRACTION OF EVENT WAVEFORMS

A. CURRENT STATUS

Long-period bodywaves were beamed to form a data base. Software was developed to beamform both compressional waves and shear waves. An adaptive filter was also developed to extract these waves based on their expected polarization. The observed particle motion was far removed from the expected particle motion. Therefore, it appears to be impractical to use it as a basis for polarization filtering. Three methods of extracting weak surface waves were tested. These are the Wiener filter, three component adaptive filter (TCA), and matched filter. These processes were cascaded to provide gains over any one of the processes. The results were favorable for cascading the Wiener filter and the TCA filter. Losses were obtained by matched filtering the output of the cascaded Wiener and TCA filters. This was due to severe signal distortion caused by the TCA filtering. This reduced the correlation coefficient of the input to the output by 0.4 to 0.6. This distortion of the signal by TCA will probably set a lower limit on the input S/N below which losses will be obtained by matched filtering.

B. FUTURE PLANS

In the next quarter, a new processor will be developed for the extraction of bodywaves based on a search for bodywave polarizations which may exist at any orientation. This orientation parameter will also be allowed to change as a function of frequency.

With respect to cascade filtering tests will be carried out to determine a lower S/N limit down to which level matched filtering can possibly yield significant gains.

SECTION V
INTERACTIVE SEISMIC PROCESSING

A. CURRENT STATUS

During the past quarter work was begun to develop an improved interactive seismic processing system on the PDP-15 computer. This will support the preparation of standard seismic processing functions to be used for routine seismic event analysis. The system is based on the existing Interactive Seismic Processing System (ISPS) and support the following features:

- Standard processing functions, developed and tested using the present fully interactive version of ISPS, can be programmed and set with the desired constraints and automation required for standard processing.
- The definition of functions by a user can range from a fully interactive to a fully automatic mode of operation.
- Accepted standard processing functions are automatically stored for convenient future use.
- The programmable mode of operation enables the use of all of the general features now offered by ISPS.

B. FUTURE PLANS

In the next quarter work will begin on the design of additional ISPS program and data structures. These must be developed to extend the system so it will support the features currently developed. The modifications will mainly impact those ISPS support routines which are responsible for

handling the user's capability of menu picking and the user's capability of entering numeric data. Changes will be made to permit storage and recall of the user's menu picks via a procedure matrix. Once this facility is checked out, changes will be made to permit storage and recall of numeric data by means of a numeric input matrix.

SECTION VI

SOURCE PARAMETERS FROM LONG-PERIOD SURFACE WAVE DATA

A. CURRENT STATUS

Computer programs pertinent to the source parameter study were converted to the TS system. The in-program documentation of these programs was completed. Programs, originally developed to generate theoretical Rayleigh (LR) and Love (LQ) wave radiation patterns and spectra for a single source couple, double couple, or quadrapole, were modified to handle a point explosive source combined with a double couple source. A new program obtains estimates of source parameters by fitting observed LR and LQ spectra with theoretical spectra of a combined source.

Lists of presumed explosion events were compiled and examined for availability of satisfactory long-period waveforms with good azimuthal coverage. Some processing of waveforms was started on the PDP-15 computer to obtain the surface wave spectra. Event-station path group velocity curves were examined for the Nevada Test Site (NTS) and eastern Kazakh (EKZ) paths to the Alaskan Long Period Array (ALPA), to the Large Aperture Seismic Array (LASA), and to the Norwegian Seismic Array (NORSAR). Shapes of dispersion curves from different NTS events over nearly the same path were very similar but were displaced possibly due to small event location or timing errors. Similar comparisons of EKZ events were more dissimilar in shape due to poorer data quality.

Layered half space models were obtained for possible use at NTS to obtain theoretical medium responses using Harkrider's dispersion analysis program. Two structures were found to be appropriate for NTS

events. One was Alexander's (1963) 35CM2 model for events near (37°N 116° W) and the other was Eaton's model modified by Toksoz et al. (1965) for events near (37°N, 116°W). Since the NTS events examined occurred near (37°N, 116°W) Alexander's model was chosen. To handle a combined earthquake source induced by an explosion, a combined source estimation problem was formulated using two approaches. In the first, the two combined sources were jointly estimated. In the second, the earthquake was estimated first by fitting LQ data and fitting a double couple source followed by use of the compressional and double couple sources. The first approach has been implemented and the second is in preparation.

B. FUTURE PLANS

Software will be developed to produce observed surface wave spectra with corrections for travel path and instrument response measurements. The second approach of formulating the combined source problem described under Current Status will be implemented.

The processing of edited signals to obtain surface wave spectra will be continued for the remaining events to be processed. The surface wave spectra corrected for travel path and instrument response will be started during the second quarter.

Further examinations of event location-station group velocity curves will be continued. The layered half space earth models for EKZ and presumed Peaceful Nuclear Explosion (PNE) locations will be constructed. Their medium response solutions will be obtained in the same way that the NTS location was obtained. Corrected surface wave spectra will also be examined as they become available.

SECTION VII
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